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Field Synergy Analysis of Combustion Characteristics in the Afterburner of Solid Oxide Fuel Cell System

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Abstract : The solid oxide fuel cell (SOFC) is a promising green technology which can achieve a high electrical efficiency. Due to the high operating temperature of SOFC stack, the off-gases at high temperature from anode and cathode outlets are introduced into an afterburner to convert the chemical energy into thermal energy by combustion. The heat is recovered to preheat the fresh air and fuel gases before they pass through the stack during the SOFC power generation system operation. For an afterburner of the SOFC system, the temperature control with a good thermal uniformity is important. A burner with a well-designed geometry usually can achieve a satisfactory performance. To design an afterburner for an SOFC system, the computational fluid dynamics (CFD) simulation is adoptable. In this paper, the hydrogen combustion characteristics in an afterburner with simple geometry are studied by using CFD. The burner is constructed by a cylinder chamber with the configuration of a fuel gas inlet, an air inlet, and an exhaust outlet. The flow field and temperature distributions inside the afterburner under different fuel and air flow rates are analyzed. To improve the temperature uniformity of the afterburner during the SOFC system operation, the flow paths of anode/cathode off-gases are varied by changing the positions of fuels and air inlet channel to improve the heat and flow field synergy in the burner furnace. Because the air flow rate is much larger than the fuel gas, the flow structure and heat transfer in the afterburner is dominated by the air flow path. The present work studied the effects of fluid flow structures on the combustion characteristics of an SOFC afterburner by three simulation models with a cylindrical combustion chamber and a tapered outlet. All walls in the afterburner are assumed to be no-slip and adiabatic. In each case, two set of parameters are simulated to study the transport phenomena of hydrogen combustion. The equivalence ratios are in the range of 0.08 to 0.1. Finally, the pattern factor for the simulation cases is calculated to investigate the effect of gas inlet locations on the temperature uniformity of the SOFC afterburner. The results show that the temperature uniformity of the exhaust gas can be improved by simply adjusting the position of the gas inlet. The field synergy analysis indicates the design of the fluid flow paths should be in the way that can significantly contribute to the heat transfer, i.e. the field synergy angle should be as small as possible. In the study cases, the averaged synergy angle of the burner is about 85°, 84°, and 81° respectively.

Keywords : afterburner, combustion, field synergy, solid oxide fuel cell
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